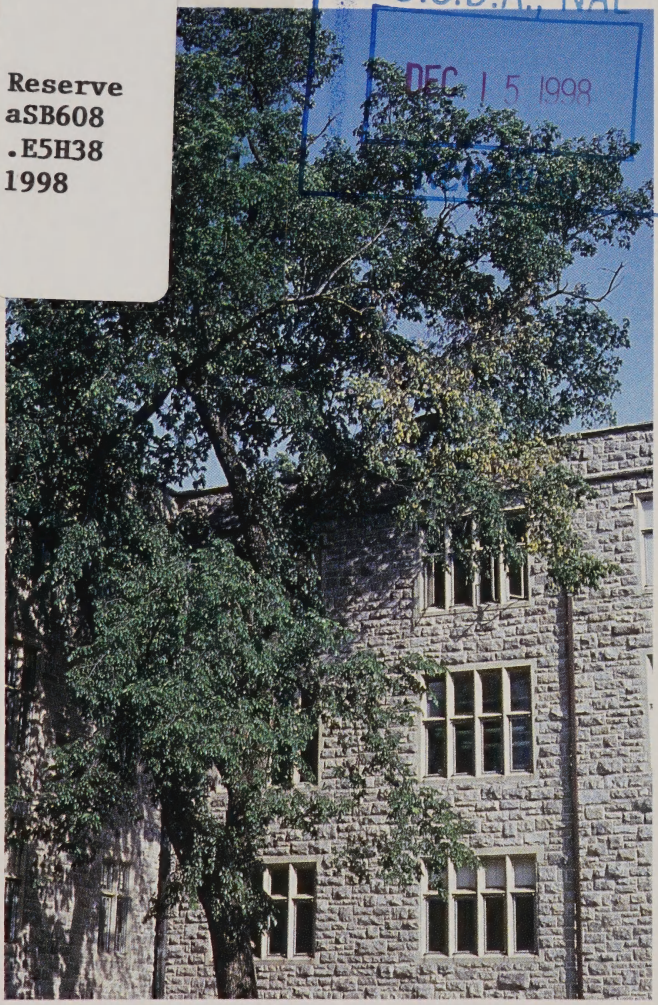
HOW to

Identify and Manage Dutch Elm Disease



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Cover photo: Branch flagging symptoms from a single point of Dutch elm disease infection in the crown of an elm.

(Photo courtesy of Dr. R. Jay Stipes, Virginia Polytechnic Institute and State University)

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Introduction

At one time, the American elm was considered to be an ideal street tree because it was graceful, long-lived, fast growing, and tolerant of compacted soils and air pollution. Then Dutch elm disease (DED) was introduced and began devastating the elm population. Estimates of DED losses of elm in communities and woodlands across the U.S. are staggering (figure 1). Because elm is so well-suited to urban environments, it continues to be a valued component of the urban forest despite the losses from DED. The challenge before us is to reduce the loss of remaining elms and to choose suitable replacement trees for the ones we cannot save.

This guide provides urban foresters and tree care specialists with the latest information and management options available for Dutch elm disease.

Figure 1. This photo is all too typical of the devastation caused by Dutch elm disease. Once a tree in a row is infected, the disease can move through connected root systems to kill the entire row.

(Photo courtesy of USDA Forest Service via Dr. R. Jay Stipes, Virginia Polytechnic Institute and State University)

Symptoms

DED symptoms are the result of a fungus infecting the vascular (water conducting) system of the tree. Infection by the fungus results in clogging of vascular tissues, which prevents water movement to the crown and causes visual symptoms as the tree wilts and dies.

Figure 2. Branch death, or flagging, at multiple locations in the crown of a diseased elm.

(Photo courtesy of Dr. Steve Katovich, USDA Forest Service, St. Paul, MN)

Foliage symptoms. Symptoms of DED begin as wilting of leaves and proceed to yellowing and browning. The pattern of symptom progression within the crown varies depending on where the fungus is introduced into the tree. If the fungus enters the tree through roots grafted to infected trees (see disease cycle section), the symptoms may begin in the lower crown on the side nearest the graft and the entire crown may be affected very rapidly. If infection begins in the upper crown, symptoms often first appear at the end of an individual branch (called "flagging") and progress downward in the crown (cover photo).

Multiple branches may be individually infected, resulting in symptom development at several locations in the crown (figure 2). Symptoms begin in late spring or any time later during the growing season. However, if the tree was infected the previous year (and the infection was not detected), symptoms may first be observed in early spring. Symptoms may progress throughout the whole tree in a single season, or may take two or more years.

Vascular symptoms. Branches and stems of elms infected by the DED fungus typically develop dark streaks of discoloration. To detect discoloration, cut through and peel off the bark of a dying branch to expose the outer rings of wood. In newly infected branches, brown streaks appear in the sapwood of the current year (figure 3). It is important to cut deeply into the wood or look at the branch in cross section for two reasons: (1) As the season progresses, the staining may be overlaid by unstained wood, and (2) if infection occurred in the previous year, the current sapwood may not be discolored.

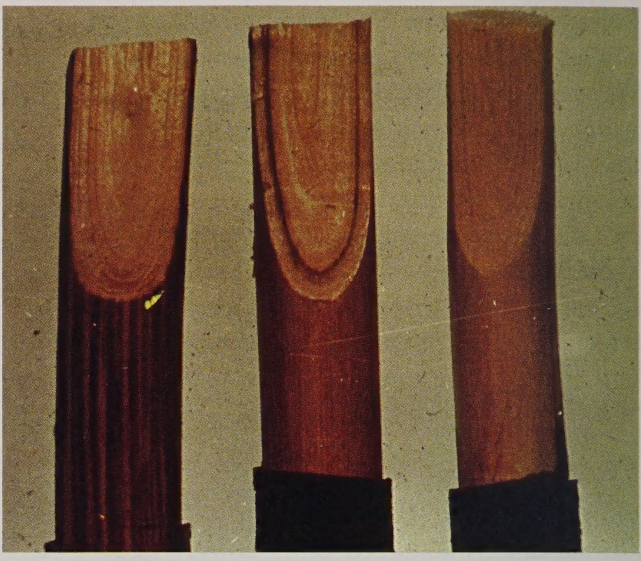

Figure 3. Brown streaking develops in sapwood of branches infected by Dutch elm disease fungus. Streaking is visible here (from left to right) in: (1) the newly formed sapwood, (2) spring sapwood overlaid by uninfected summer wood, and (3) is absent in an uninfected branch.

(Photo courtesy of the American Phytopathological Society)

Distinguishing Dutch Elm Disease From Other Problems

Other pest problems commonly observed on elm include leaf spot diseases, which cause dark spots of dead tissue in the leaves, and elm leaf beetles, which eat holes in the leaves. These problems are easily distinguished from DED. Elm leaf beetles do not carry the Dutch elm disease fungus as elm bark beetles do.

Two other diseases, elm yellows and bacterial leaf scorch, are more easily confused with DED. The symptoms of these diseases are compared to DED in table 1.

Elm yellows. This disease, which is also called elm phloem necrosis, is caused by a phytoplasma

Table 1. Comparison of symptoms of three elm diseases.

Dutch Elm Disease	Elm Yellows	Bacterial Leaf Scorch
Initally affects individual branches OR Affects lower crown nearest point of root graft.	Affects the entire crown.	Damage initially observed on single branches, and spreads to entire crown; oldest leaves are affected first.
Leaves wilt and turn yellow, then brown.	Leaves turn yellow and may drop early.	Leaves brown along margin, with a yellow halo.
Symptoms often first observed in early summer, but may be exhibited any time of the growing season.	Symptoms visible from July to September.	Symptoms appear in summer and early fall.
Brown streaking in sapwood.	No discoloration in sapwood.	No discoloration in sapwood.
No discoloration of inner bark.	Tan discoloration of inner bark.	No discoloration of inner bark.
No wintergreen odor.	Wintergreen odor in inner bark.	No wintergreen odor.

(microscopic bacteria-like organism) which systemically infects the phloem tissue (inner bark) of the tree. It is a serious disease that causes tree death. Symptoms of elm yellows differ from DED in that the leaves turn yellow (not brown and wilted) and drop prematurely, and the symptoms appear in the entire crown at the same time. The brown streaking which DED causes in the sapwood is absent, but the inner bark develops a tan discoloration and a characteristic wintergreen odor.

Bacterial leaf scorch. This disease is caused by the bacterium *Xylella fastidiosa*, which infects and clogs the water conducting tissues of the tree. Infection by this bacterium causes a slow decline over many years. Once a tree is infected, symptoms recur annually. Symptoms of scorch are irregular browning along the leaf margin with a yellow border between green and scorched leaf tissue. Older leaves on a branch are affected first.

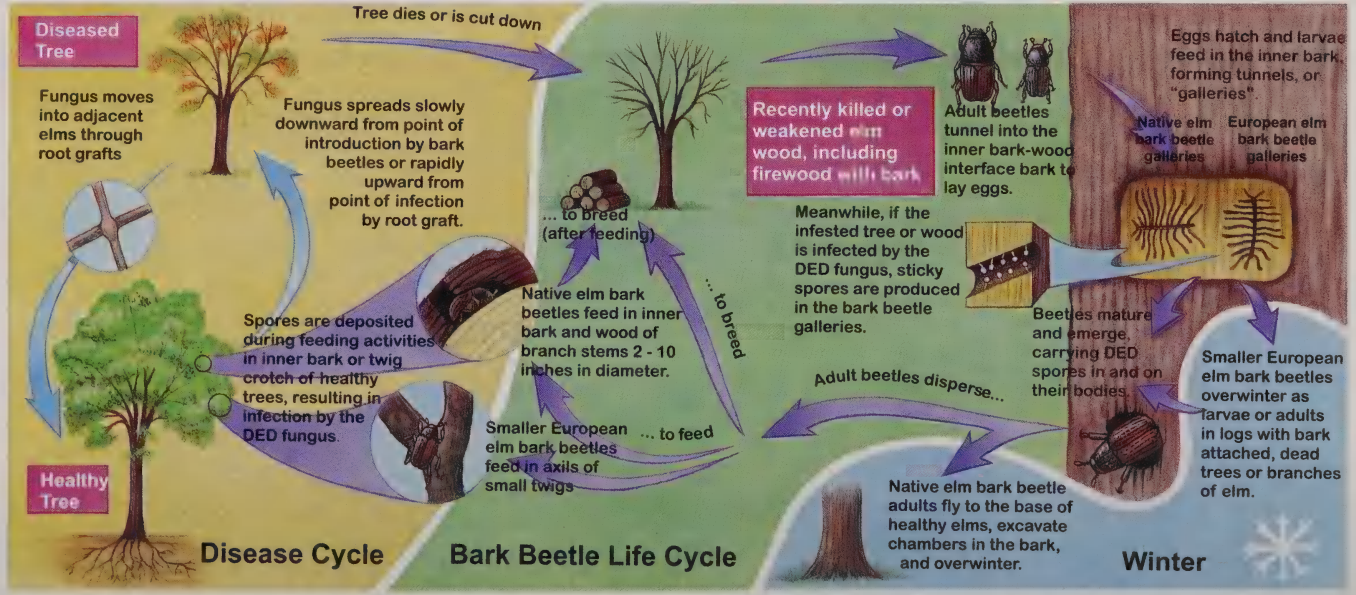

Figure 4. The disease cycle of Dutch elm disease is closely linked to the life cycles of elm bark beetles.

(Artwork by Julie Martinez, Scientific Illustrator, St. Paul, MN)

Disease Cycle of Dutch Elm Disease

The biology, or "disease cycle," of DED depends upon the host, the fungus and the means by which the fungus moves into new host trees (figure 4).

The elm host. Native species of North American elms vary in their susceptibility to DED, even within species. American elm (*Ulmus americana* L.) is generally highly susceptible. Winged elm (*U. alata* Michx.), September elm (*U. serotina* Sarg.), slippery elm (*U. rubra* Muhl.), rock elm (*U. thomasii* Sarg.), and cedar elm (*U. crassifolia* Nutt.) range from susceptible to somewhat resistant. No native elms are immune to DED, but some individuals or cultivars have a higher tolerance (and thus may recover from or survive with infection) or resistance to DED. Many European and Asiatic elms are less susceptible than American elm.

In addition to genetic factors present in some cultivars and species, physical factors affect tree susceptibility. These factors include time of year, climatic conditions (such as drought) and vitality of the tree. Water conducting elements are most susceptible to infection as they are being produced in the spring, thus elms are most susceptible to infection after earliest leafing out to midsummer. Trees are less susceptible under drought conditions. Vigorously growing trees are generally more susceptible than slower growing trees.

The Dutch elm disease fungus. DED can be caused by either of two closely related species of fungi: *Ophiostoma ulmi* (Buism.) Nannf. (formerly called *Ceratocystis ulmi*) and *Ophiostoma novo-ulmi* Brasier. The latter, which is more aggressive in causing disease, was recently recognized as being a separate species. The DED fungus was first introduced to the U.S. on diseased elm logs from Europe prior to 1930. It is unknown when the more aggressive species became established in the U.S.;

however, it was possibly present as early as the 1940s - 1950s, and most likely caused much of the devastating mortality through the 1970s. The less aggressive species is becoming increasingly rare in nature, and the aggressive species is thought to be responsible for most of the current mortality. Although some local resurgence of DED has been observed, there is no evidence that it is due to a change in the pathogen. Localized resurgence is more likely due to the following: (1) a decrease in vigilance in monitoring and sanitation, (2) a build-up in populations of the insect vectors, or (3) ingrowth of susceptible host trees in the wild.

Spread by elm bark beetles. Overland spread of DED is closely linked to the life cycles of the native elm bark beetle (*Hylurgopinus rufipes* Eich.) and the smaller European elm bark beetle (*Scolytus multistriatus* Marsh.) (figure 5). Both beetles are attracted to stressed, dying or dead elm wood to complete the breeding stage of their life cycle. The adult beetles tunnel into the bark and lay their eggs in tunnels (called galleries) in the inner bark. The eggs hatch and the larvae feed in the inner bark and sapwood.

The larvae mature into adults and emerge from the elm wood. If the DED fungus was present in the wood that the beetles infested, the fungus produces sticky spores in the beetle galleries. Spores of the DED fungus are eaten by or stick to the adult beetles as they emerge from diseased trees. Adult beetles then visit healthy trees, feed in twig crotches or branch inner bark, and introduce the fungus into or near severed wood vessels as they feed.

The importance of the two bark beetle species as vectors of DED varies across the range of elms. In northern areas (northern parts of Minnesota, Wisconsin, Maine, New York and New England and most of Canada, where winter temperatures below –6 °F are common), the native elm bark beetle is

Figure 5. Overland spread of DED is closely tied to the life cycles of the native elm bark beetle (top) and smaller European elm bark beetle (below). Note that the smaller European elm bark beetle is actually larger than the native elm bark beetle.

(Artwork by Julie Martinez, Scientific Illustrator, St. Paul, MN)

the predominant vector. In other parts of North America, the smaller European elm bark beetle predominates. The life habits of the adults of the two species differ considerably, which has implications for management opportunities. These differences are described below.

Smaller European elm bark beetles overwinter as larvae or adults within the stem of the tree where they hatched. They emerge as adults in spring to feed in twig crotches of healthy trees, where they can introduce spores of the DED fungus to the crown. High numbers of beetles frequently will feed in a single tree, resulting in multiple points of

infection. The cycle is repeated when beetles then seek out diseased and dying wood to breed in throughout the growing season, completing two or more generations per year. They have the potential to rapidly build up high populations.

Adult native elm bark beetles tunnel into the bark on the lower stems of healthy elms to overwinter. In spring they emerge to feed in the inner bark of elm branches and small stems before beginning their breeding cycle. They repeat their life cycle as previously described. They can transmit the DED fungus to healthy trees during the construction of overwintering sites in fall, or, more commonly, during feeding in spring.

Once the DED fungus is introduced into the upper crown of healthy elms by bark beetles, it slowly moves downward, killing the branch as it goes. Disease progression may occur rapidly, killing the tree by the end of the growing season, or may progress gradually over a period of two or more years. It is also possible that the tree may recover. The success and rate of progression within the tree depends on tree size, time and location of infection in the tree, climatic conditions, and response of the host tree.

Spread through grafted roots. Roots of the same or closely related tree species growing near each other often cross each other in the soil and eventually fuse (become grafted) to each other. The DED fungus can move from infected trees to adjacent trees through these grafted roots. Infections that occur through root grafts can spread very rapidly throughout the tree, as the fungus is carried upward in the sapstream. Root graft spread of DED is a very significant cause of tree death in urban areas where elms are closely spaced (figure 6).

Figure 6. Where elms are closely spaced, the Dutch elm disease fungus may move down a row of trees through grafted roots. Removing trees without breaking root grafts may not keep the fungus from moving into adjacent trees.
(Photo courtesy of Dr. Joseph O'Brien, USDA Forest Service, St. Paul, MN)

Managing Dutch Elm Disease

DED is managed by interrupting the disease cycle. The most effective means of breaking the cycle is early and thorough sanitation to limit the population of the insects that transmit the fungus from tree to tree. Other useful means of affecting the disease cycle include using insecticides to kill the insect vector, breaking root grafts between trees, injecting individual trees with fungicides to prevent or halt the fungus, pruning out early infections, and planting DED tolerant or resistant elm cultivars or other tree species.

Sanitation to reduce insect vectors. Many communities have been able to maintain a healthy population of mature elms through a vigilant program of identification and removal of diseased elms and systematic pruning of weakened, dying or dead branches. Sanitation by prompt removal of diseased trees or branches reduces breeding sites for elm bark beetles and eliminates the source of the DED fungus. To be completely effective in interrupting the spread of the disease by elm bark beetles, stems and branches of DED infected trees must be de-barked, destroyed, or utilized before the bark beetles emerge. During the growing season, removal should be completed within 2 to 3 weeks of detection. During the dormant season, removal should be completed before April, when over-wintering beetles may begin to emerge.

Wood from infected trees can be destroyed by chipping, burning or burying. Wood may be retained for use as firewood or sawlogs if it is de-barked or covered from April 15th to October 15th with 4 to 6 mil plastic. The edges of the cover must be buried or sealed to the ground. If it is impossible to destroy all elm wood before the beetles emerge, the wood can be sprayed with a registered insecticide until disposal is possible. If insecticides are used, consider potential exposure to chemical

residues when burning or handling the treated wood. Many communities have regulations on the removal of diseased elms and storage of elm firewood; make sure your activities comply with local regulations.

Insecticides to kill insect vectors. In areas where the native elm bark beetle is the principal vector, sanitation may be augmented by applying a registered insecticide to the lower stem of healthy elms in late summer to early fall (i.e., at the first sign of autumn leaf color change) to kill adult beetles as they prepare overwintering sites. In areas where the smaller European elm bark beetle is common, spring feeding in twig crotches can be prevented by spraying the crowns of elm trees with a registered insecticide. However, this may not be a preferred treatment method because of the difficulty in getting thorough coverage of all susceptible twig tissue, the risk of insecticide drift and exposure, and high expense.

Insecticide registrations and recommendations are frequently updated, and may vary considerably between states. Cooperative Extension Services at land grant colleges and certified arborists are able to provide current insecticide recommendations.

Disruption of root grafts. Large elms within 25 to 50 feet of each other are likely to have root grafts. Breaking root grafts between infected trees and adjacent healthy trees is an important means to prevent movement of the fungus into the healthy trees. Root grafts should also be disrupted between the healthy tree adjacent to a diseased tree and the next healthy tree. It may even be desirable to sever grafts between very valuable trees before DED is observed in the vicinity, as a proactive measure.

Root graft disruption should be completed before the infected trees are removed. Otherwise the transpirational pull from healthy trees will rapidly draw in the contents of diseased tree's root system when the

vascular tension on the roots of the diseased tree is released by severing the stem. Root graft disruption can be accomplished by use of a vibratory plow or any trenching machine equipped with the longest blade available (preferably five feet long, but at least three feet long). Biocidal soil fumigants may also be used to kill root grafts if no other alternatives are available. However, these chemicals are generally restricted use pesticides and may only be applied by professional pesticide applicators. In addition, biocidal chemicals may not be effective if soil temperatures are below 50 °F.

Injecting elms with fungicide. Certain fungicides, when properly injected, are effective in protecting elm trees from infection via beetle transmission. This treatment is expensive and must be repeated every one to three seasons, thus it is appropriate only for high value or historically important trees. The treatment itself also may pose risks to the health of the tree.

In order to be effective, the fungicide must be present at adequate concentration at all potential points of infection. Thus the dosage and means of application are critical to success. The injection of chemical into root flares in large volumes of water (macroinjection) provides thorough distribution of chemical in the crown (figure 7). Microinjection (injection of small volumes of concentrated chemical) is also an option, although its efficacy compared to macroinjection has not been thoroughly researched. Preferably, injections should be done soon after the earliest leaves have fully expanded, but may be done from then to the end of the growing season. Label rates of concentration for chemical application are updated to reflect the most recent findings on effectiveness; always follow the current label.

Figure 7. Macroinjection of fungicide into the root flare of an elm tree.
(Photo courtesy of Mark Stennes, certified arborist, St. Paul, MN)

Harmful effects of fungicide injection have sometimes been reported and include occasional leaf "scorching" or loss. Elms generally recover from this damage. Also, drilling injection holes results in wounding which, if repeated annually, may eventually result in significant discoloration and decay. Following fungicide injection with a flush of clean water can reduce damage to the cambium. Some chemicals are able to protect trees for up to three seasons, thus minimizing the frequency of treatments.

Several fungicides are registered for injection to prevent DED infection. These chemicals vary in duration of protective effects, means of application, risk of damage to the tree, documentation of effectiveness, and cost. Certified arborists or Cooperative Extension Services at land grant colleges are able to provide current recommendations on product availability and effectiveness.

Eradicating Dutch elm disease from newly infected trees. If a new crown infection of DED is detected early enough, there is opportunity to save a tree through pruning, fungicide injection, or both. Eradicative treatment is not possible on trees that have become infected via root graft transmission. Pruning, which can literally eradicate the fungus from the tree by removing it, has a high probability of "saving" a newly infected tree that has less than 5% of its crown affected. To be a candidate for eradicative pruning, the infection must be a new infection (not a residual infection from the previous season) and be present only in the upper crown (not yet present in the main stem). Since infection may be more advanced than symptoms indicate, it is important to peel off the bark of infected branches and locate the staining, which indicates the presence of the fungus. All infected branches should be removed at a branch fork at least 5 feet, and preferably 10 feet, below the last sign of streaking in the sapwood (figure 8). Whenever elm branches are pruned during the growing season, pruning paint specifically formulated for use on trees should be applied to prevent attraction of elm bark beetles to the wounded trees. (Painting tree wounds is generally not recommended, except to prevent disease transmission in oaks and elms.)

Pruning is more likely to be effective if augmented by systemic injection of fungicides. Proper use of fungicides eliminates the need to eradicate all infected tissues from the tree, although all dead branches should eventually be removed. Whereas pruning alone is not effective against residual infections, fungicide injection may be. If fungicides are used, they should be injected prior to removal of diseased branches. The keys to successful eradicative treatment are early detection and prompt treatment.

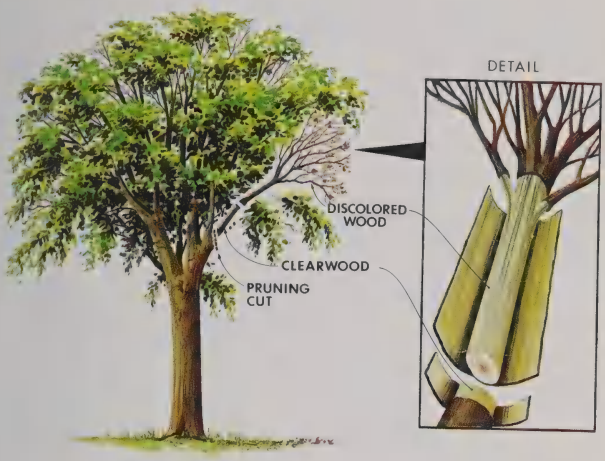

Figure 8. Eradicative pruning of branches infected with DED may be effective if there is adequate length (5 to 10 feet) of clearwood between the infected tissue and the remainder of the crown, or if the tree has been properly treated with fungicide.

(Artwork courtesy of Jim Lockyer, USDA Forest Service, Radnor, PA)

Planting Dutch elm disease resistant or tolerant trees. Planting trees with resistance or tolerance to DED is a valid management option. However, selecting only a few cultivars limits the genetic variability of the population. This could lead to increased risk of widespread losses if these cultivars are found to be susceptible to tree health problems such as poor adaptation to site, air pollution, other elm pests or pathogens (such as elm yellows or elm leaf beetle) or even other strains of DED which may eventually develop. Thus it is prudent to plant a mixture of suitable cultivars of as many elm genotypes as possible.

Santamour and Bentz (1995) recently published a checklist and brief description of elm cultivars in North America. The only true American elms on that list that are commercially available and have strong evidence of DED tolerance or resistance are the Princeton Elm, the American Liberty "multi-

clone," and Independence, which is one of the cultivars in the American Liberty multi-clone. Two additional American elms, Valley Forge and New Harmony, were released by the USDA National Arboretum since the Santamour and Bentz listing was prepared. These two cultivars, which exhibit high tolerance to DED, should be available through retail nurseries by 2001.

Besides true American elms, there are many other hybrid elm crosses and species of elm that have high tolerance or resistance to DED. Several of these have attractive form, are well suited to urban environments, and are readily available (figure 9). Many of these are listed and described by Santamour and Bentz (1995) in the previously mentioned checklist.

In addition to careful selection of the tree species and cultivar, location and spacing are also important to reduce losses from DED. When selecting landscape trees and their locations, plant a mixture of tree species appropriate to the site. In addition to the species diversity, consider spacing of the trees. Future problems with root grafts can be avoided by carefully selecting planting location and maximizing tree species diversity.

Figure 9. Cultivars of elm selected for resistance to DED are available. This selection of *Ulmus japonica* demonstrates the potential these elms have as landscape trees.

(Photo courtesy of Dr. Eugene Smalley, University of Wisconsin—Madison)

Trees in Natural Stands or Wild Areas

Infected elms in wild areas and natural stands that are within or near urban areas often serve as a reservoir of elm bark beetles and DED fungus to infect high value landscape trees. Management is necessary in order to protect urban elms.

The most effective management option to reduce both the bark beetle vectors and the DED fungus is sanitation to promptly remove stressed, dead and dying elms as previously described. However, this intensity of treatment is often not feasible.

A "trap tree" method was developed in the 1980s to more cost effectively reduce populations of elm bark beetles. Under this method, DED infected elms which are still living are treated with an herbicide that kills the tree quickly and promotes rapid drying out of the bark. The bark beetles are attracted to the dying trees, but the rapidly drying bark is unsuitable for them to complete their lifecycle, and the bark beetle populations are reduced. However, treated trees may then become hazard trees with high risk of falling and causing personal injury or property damage.

Another option in wild areas or natural stands, other than accepting losses from DED, is to eliminate all elms and manage for alternative species. However, it is often desirable to retain elms for biodiversity, aesthetic, economic, or other reasons.

Deciding Which Management Practices to Use

Different management strategies will be applicable depending on whether you are working with a community program or trying to protect individual trees. In a community program, the objective will be to protect a population of elms. Individual landowners, however, may have no control over what neighbors do with their elms but may want to protect or save their own trees. The amount of money an individual or community is able to spend will also vary.

Where you have no control over the management of surrounding trees, the only options available are treatments to protect or save individual trees. Good sanitation practices and disruption of root grafts are necessary on individual properties, but these practices alone will not protect a tree from disease transmission by bark beetles from other properties. Preventive fungicide injection, eradicative pruning and fungicide injection, and insecticide treatment are generally the only options available for individual trees.

In a community program, resources to spend on individual trees may be low, but there is more opportunity to manage populations of elms. Where there are continuous elms, root graft disruption is essential to halt the spread. Sanitation is key to reducing beetle and DED populations, and is effective. Community ordinances can be established to encourage prompt removal of diseased trees and prevent the storage of elm wood with bark intact. Education will help citizens understand the importance and benefits of working together to manage DED. As resources allow, preventive treatment, eradicative treatment and insecticides can be used to augment a program. If you are working with a community with a significant elm resource, become familiar with the

literature listed in the bibliography and with what has worked well in other communities.

The impact of DED on our urban forests has been massive. Despite the losses, elms should and will continue to be a component of many urban forests. We have an opportunity to consider what trees will compose the future urban forest, and we can learn from the past. Landowners and communities can and should choose carefully what types of trees to plant and where to plant them.

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Pesticide Precautionary Statement:
Pesticides used improperly can be injurious to humans, animals, and plants. Follow label directions and heed all precautions on the labels. Store all pesticides in original containers, out of reach of children and foodstuffs. Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. After handling a pesticide, do not eat, drink, or smoke until you have washed. Dispose of empty pesticide containers properly. It is difficult to remove all traces of a herbicide (weed killer) from equipment. Therefore, to prevent injury to desirable plants do not use the same equipment for insecticides that you use for herbicides.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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For further information, contact: